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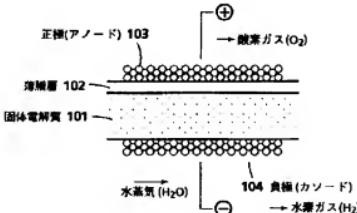
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## (54)【発明の名称】 固体電解質

## (57)【要約】

【目的】 良好的なガス拡散能を保持しつつ、有効反応面積を増加し、且つ電解操作時等の閉空間内酸素圧の上昇を緩和することができる固体電解質を提供する。

【構成】 両面に正極及び負極を配し、高温型水蒸気電解質若しくは高温型燃料電池に用いてなる固体電解質において、上記正極側の固体電解質本体101の表面に導電性薄膜層102を設けると共に、当該薄膜層102の表面に多孔質正極103を設け、他方側には負極104を配してなる。



## 【特許請求の範囲】

【請求項1】両面に正極及び負極を配し、高温型水蒸気電解質若しくは高温型燃料電池等に用いてなる固体電解質において、

上記正極側の固体電解質本体の表面に導電性薄膜層を設けると共に、当該薄膜層の表面に多孔質正極を設けてなることを特徴とする固体電解質。

## 【発明の詳細な説明】

## 【0001】

【産業上の利用分野】本発明は、固体電解質を用いる高温型の水蒸気電解及び固体電解質燃料電池（SOFC: Solid Oxide Fuel Cell）若しくは酸素センサ等に用いて好適な固体電解質に関する。

## 【0002】

【従来の技術】高温型水蒸気電解セルには、大別して平板型と円筒型があり、この内の平板型の水蒸気電解の構成及びその原理図を図6及び図8に示す。ここで使用している固体電解質11には、イットリアで安定化させたジルコニア（YSZ: Yttria Stabilized Zirconia）を用いている。このYSZは、酸素イオン（O<sup>2-</sup>）だけを選択的に透過する性質をもっており、図6に示すように、負（カソード）極12側に水蒸気（H<sub>2</sub>O）、正（アノード）極13側に酸素（O<sub>2</sub>）を各々供給し、外部の直流電流14より電流を流すにより、固体電解質11中を酸素イオン（O<sup>2-</sup>）だけが移動する。

【0003】図8によると、負極12側に供給された水蒸気（H<sub>2</sub>O）は酸素イオン（O<sup>2-</sup>）をうばわれ、水素（H<sub>2</sub>）のみとなり、一方、固体電解質11中を移動した酸素イオン（O<sup>2-</sup>）は、正極13で電子（e<sup>-</sup>）を放出し、酸素ガス（O<sub>2</sub>）となる。このようにして、固体電解質11にYSZを用いて水蒸気（H<sub>2</sub>O）を酸素ガス（O<sub>2</sub>）と、水素ガス（H<sub>2</sub>）とに分解（電解）することができ、電解により水素（H<sub>2</sub>）を得ることができる。

【0004】次に、同様なセル構造を有する固体高分子電解質燃料電池の一例を、図9に示す。同図に示すように、固体高分子電解質21としてフッ素樹脂系の高分子イオン交換膜（例えはスルホン酸基を持つフッ素樹脂系イオン交換膜）を用い、これを中央にして両面に負（カソード）極22及び正（アノード）極23を付着させ、各々の電極22、23に水素（H<sub>2</sub>）、酸素（O<sub>2</sub>）を供給している。ここで、正極23側に供給された燃料中の水素（H<sub>2</sub>）は、図9に示すように、その正極23上で水素イオン化され、水素イオン（H<sup>+</sup>）は電解質21中を水の介在のもと、H<sup>+</sup> + H<sub>2</sub>O → 負極22側へ移動する。負極22上で酸化剤中の酸素（O<sub>2</sub>）及び外部回路24を通過してきた電子（e<sup>-</sup>）と反応して水（H<sub>2</sub>O）を生成し、燃料電池外へ排出される。この時、外部回路24を通過した電子（e<sup>-</sup>）の流れが直流水の電気エネルギーとして利用できる。

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## 【0005】

【発明が解決しようとする課題】前述した構成により水蒸気電解及び燃料電池操作が行なわれるが、このとき電極反応が起こる場所は、水蒸気電解を例にとると、図7に示すように、固体電解質11と正極13及び酸素ガス（O<sub>2</sub>）が接する三相界面15に限定される。この結果、電極性能を向上させるためには、電極を密に作製する必要がある。しかしながら、電極を密に作製した場合には、ガス拡散能が悪くなり、その結果、電極性能が悪化し逆効果となる。

【0006】また、水蒸気電解操作を行う場合、強制的に通電するが、このとき固体電解質／正極界面に閉空間が存在すると、その閉空間内における酸素圧が異常に高まり、電極が剥離するという問題がある。例えばLa<sub>2</sub>Si<sub>1-x</sub>Mn<sub>x</sub>O<sub>3</sub>を正極として閉空間があった場合、6.00mA/cm<sup>2</sup>の通電を行ったところ、1時間以内に剥れてしまうという問題があった。

【0007】本発明は以上述べた事情に鑑み、良好なガス拡散能を保持しつつ、有効反応面積を増加し、且つ電解操作等時の開閉間で酸素の上昇を緩和することができる固体電解質を提供することを目的とする。

## 【0008】

【課題を解決するための手段】前記目的を達成する本発明に係る固体電解質の構成は、両面に正極及び負極を配し、高温型水蒸気電解質若しくは高温型燃料電池等に用いてなる固体電解質において、上記正極側の固体電解質本体の表面に導電性薄膜層を設けると共に、当該薄膜層の表面に多孔質正極を設けてなることを特徴とする。

【0009】以下、本発明の内容を説明する。

【0010】図1に本発明に係る固体電解質を平板型高温電解に用いた概略を示す。同図に示すように、電解質本体101は従来と同様にYSZ（Yttria Stabilized Zirconia）からなり、その正極側となる表面には導電性薄膜層102が設けられており、この導電性薄膜層102を介して多孔質正極（La<sub>2</sub>Si<sub>1-x</sub>Mn<sub>x</sub>O<sub>3</sub>系）103が設けられている。また、電解質本体101の他方側には従来と同様の構成の負極（NiO/YSZ）104が配されている。

【0011】ここで、上記導電性薄膜層（以下「薄膜層102」という）102とは、ホール導電性及び酸素イオン導電性を有する薄い境界層をいい、この薄膜層102と気相との界面で以下「化1」に示す電極反応を起こすものをいう。また、この薄膜層102を形成する材料としては、Mn系酸化物、La<sub>2</sub>Si<sub>1-x</sub>Mn<sub>x</sub>O<sub>3</sub>、（La, Ca）MnO<sub>3</sub>、（La, Sr）MnO<sub>3</sub>等を挙げることができその厚さは0.1μm～5μmとしている。

## 【0012】

【化1】 $2O^{2-} + 4H^+ \rightarrow O_2 \uparrow \dots (1)$

【0013】すなわち、図2に示すように、正極103と薄膜層102との界面においては当該薄膜層102側

にホール ( $h^+$ ) が生成し、このホール ( $h^+$ ) が薄膜層 102 中を拡散して、上記 (1) 式の反応に供与される。

【0014】一方、図3に示すように、閉空間がある場合、この閉空間内の酸素圧が高まる、そのホール伝導性により薄膜層 102 中に電位勾配が形成されるため、当該閉空間 104 内では上記 (1) 式の逆反応である「化2」に示す反応が進行し、この結果、内圧の上昇が緩和される。

【0015】

【化2】  $O_2 \rightarrow 2O^{\cdot} + 4h^+$  … (2)

【0016】よって本発明では、正極に接する固体電解質本体 101 の表面にホール導電性及び酸素イオン導電性を有する境界層としての導電性薄膜層 102 を設けると共に、この薄膜層 102 を介して電子導電性及びガス透過性を有する多孔質電極 103 を設けたので、上記「化1」に示す電荷移動反応が固体電解質本体 101 の全表面に亘って起こすことができると共に、水蒸気電解操作時において正極閉空間内の酸素圧上昇を緩和することができる。

【0017】<試験例>次に本発明の効果を示す試験例を図面(グラフ)を参照して説明する。

【0018】図4には温度 1000°C で負極に水蒸気を供給して水蒸気電解を行った場合の正極における「電流-電位曲線」を示す。同図に示すように、電流密度(横軸)を増加すると、正極電位は性能の悪い従来のセルほど、正に大となる傾向を示す。すなわち、▲△で示した従来のYSZ界面無処理のPt走査に比べ、薄膜層を設けた●○で示す本試験例では電位の変化は小さく、一定の電流密度を得るための電圧は少なくて済むことを確認した。

【0019】また、正極に対して 600mA cm<sup>-2</sup> のアノード通電をした場合の正極の示す電位の安定性についても試験した。この結果を図5に示す。同図に示すように▲△で示す従来のYSZ界面無処理のPt電極の性能は次第に悪化する傾向を示すのに対して、薄膜層を設けた●○で示す本試験例では、130時間以上の間より低電位で安定して作動していることを確認した。

【0020】

【実施例】以下、本発明に係る固体電解質の好適な一実施例について説明する。

【0021】本実施例においては高温型水蒸気電解装置に用いる固体電解質を例にとって説明する。ここで、固体電解質本体 101 は 8mol% のイットリアで安定化

したイットリア安定化ジルコニア (YSZ) としており、0.5 μm の粒子にアルコールと界面活性剤を加えてスラリー化し、テフロンシート上にこのスラリーを載せて自然乾燥させた後、1400°C で 1 時間、空気中で焼成した。この得られた安定化ジルコニア板は 2.5 mm のディスクであり、厚さは 500 μm である。この固体電解質本体 101 の表面にスラリー化した La, Sr, MnO<sub>3</sub> (LSM) をディスクの一方の面に 1.0 mm の薄く塗布し、1300°C で焼成した。この焼成した LSM をエターリー紙で落とし、エタノールで洗浄した後、その表面に液状の Pt ベーストを薄く塗布し、1100°C で 1 時間焼成し、正極とした。

【0022】この得られた固体電解質は正極/YSZ界面に Mn 等が拡散していることを XPS (X線電子分光分析装置) によって確認した。

【0023】

【発明の効果】以上、試験例、実施例と共に述べたように、本発明に係る固体電解質は、固体電解質本体の表面に導電性薄膜層を設けたので、その全域に亘って反応が可能となる。また水蒸気電解時の閉空間内の内圧が上昇しても導電性薄膜層に電位勾配が形成されその緩和効果が発現され、従来のように電極の剥離が無く、長時間に亘って低電位で安定作動することができる。

【図面の簡単な説明】

【図1】本実施例に係る固体電解質型水蒸気電解装置の概略図である。

【図2】図1の正極近傍における反応の概説図である。

【図3】水蒸気電解時の閉空間における酸素上昇緩和反応の概説図である。

【図4】本発明と従来例との水蒸気電解における性能比較図である。

【図5】本発明と従来例との水蒸気電解における作動安定性の比較図である。

【図6】従来の固体電解質型水蒸気電解装置の原理を示す概略図である。

【図7】図6の正極近傍における反応の概説図である。

【図8】水蒸気電解の原理図である。

【図9】燃料電池の原理図である。

【符号の説明】

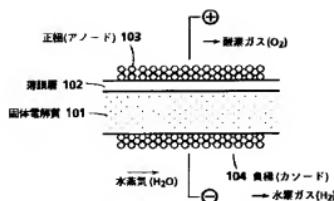
101 固体電解質本体

102 導電性薄膜層

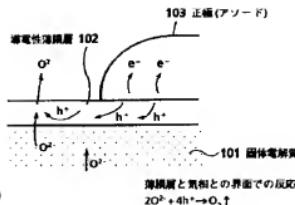
103 多孔質正極

104 負極

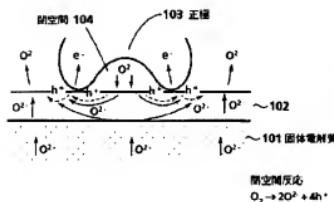
【図1】



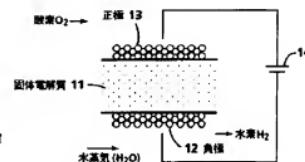
【図2】



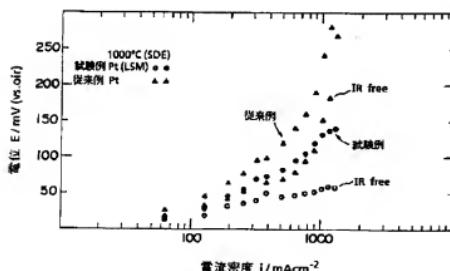
【図3】



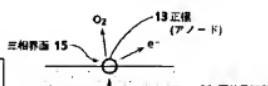
【図6】



【図4】

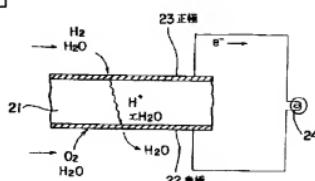


【図7】

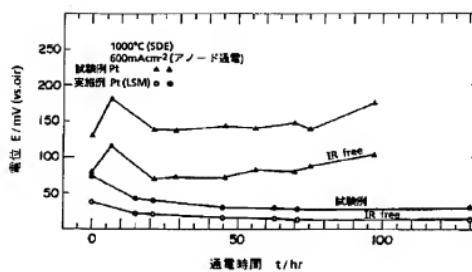


【図8】

燃料電池の原理図

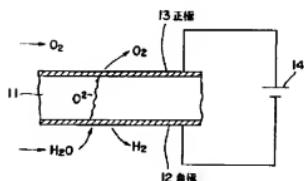


【図5】



【図8】

水蒸気電解の原理図



## PATENT ABSTRACTS OF JAPAN

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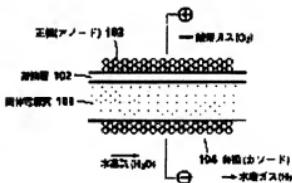
(72)Inventor : KOSHIRO YASUMASA  
 MIYAMOTO HITOSHI  
 SUMI MASAO

## (54) SOLID ELECTROLYTE

## (57)Abstract:

PURPOSE: To provide a solid electrolyte wherein an effective reaction area is increased while holding good diffusing power of gas and further a rise of oxygen pressure in closed space at the time of electrolytic operation can be relaxed.

CONSTITUTION: In a solid electrolyte formed by using it in a high temperature type steam electrolytic or high temperature type fuel cell by arranging positive and negative electrodes in both surfaces, a conductive thin film layer 102 is provided in a surface of a solid electrolyte main unit 101 in a side of the positive electrode. The electrolyte is formed by providing the porous positive electrode 103 in a surface of this thin film layer 102 and by arranging the negative electrode 104 in the other side.



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CLAIMS

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## [Claim(s)]

[Claim 1]A solid electrolyte which a conductive thin film layer is provided in the surface of a main part of a solid electrolyte by the side of the above-mentioned anode, and provides a porosity anode in the surface of the thin film layer concerned in a solid electrolyte which arranges an anode and a negative electrode on both sides, and is used for high temperature form water vapor electrolysis or a high temperature form fuel cell, and is characterized by things.

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[Translation done.]

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## DETAILED DESCRIPTION

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### [Detailed Description of the Invention]

#### [0001]

[Industrial Application]This invention is used for water vapor electrolysis and a solid electrolyte fuel cell (SOFC:Solid Oxide Fuel Cell), or an oxygen sensor of a high temperature form etc. which uses a solid electrolyte, and relates to a suitable solid electrolyte.

#### [0002]

[Description of the Prior Art]It divides roughly into a high temperature form water-vapor-electrolysis cell, there are a monotonous type and cylindrical in it, and monotonous type the composition and its principle figure of water vapor electrolysis of these are shown in drawing 6 and drawing 8. The zirconia (YSZ:YttriaStabilized Zirconia) stabilized by yttria is used for the solid electrolyte 11 currently used here. This YSZ has the character which penetrates only oxygen ion ( $O^{2-}$ ) selectively. it is shown in drawing 6 --- as --- negative (cathode) --- very --- 12 sides --- a steam ( $H_2O$ ) --- right (anode) --- only oxygen ion ( $O^{2-}$ ) moves in the inside of the solid electrolyte 11 by supplying oxygen ( $O_2$ ) to 13 sides respectively very much, and sending current from external DC power supply 14.

[0003]As shown in drawing 8, the steam ( $H_2O$ ) supplied to the negative-electrode 12 side oxygen ion ( $O^{2-}$ ) Therefore, a \*\*\*\* crack. By becoming only hydrogen ( $H_2$ ), on the other hand, the oxygen ion ( $O^{2-}$ ) which moved in the inside of the solid electrolyte 11 emits electrons ( $e^-$ ) with the anode 13, and serves as oxygen gas ( $O_2$ ). Thus, YSZ can be used for the solid electrolyte 11, a steam ( $H_2O$ ) can be disassembled into oxygen gas ( $O_2$ ) and hydrogen gas ( $H_2$ ) (electrolysis), and hydrogen ( $H_2$ ) can be obtained by electrolysis.

[0004]Next, an example of a solid polymer electrolyte fuel cell which has the same cellular structure is shown in drawing 9. As shown in the figure, the polymers ion-exchange membrane (for example, fluoro-resin system ion-exchange membrane with a sulfonic group) of a fluoro-resin system is used as the solid polymer electrolyte 21, carrying out this in the center --- both sides --- negative (cathode) --- very --- 22 --- and --- right (anode) --- 23 is made to adhere very much and hydrogen ( $H_2$ ) and oxygen ( $O_2$ ) are supplied to each electrodes 22 and 23. Here, as hydrogen ( $H_2$ ) in the fuel supplied to the anode 23 side is shown in drawing 9, it is hydrogen-ion-ized on the anode 23, and a hydrogen ion ( $H^+$ ) moves the inside of the electrolyte 21 to the negative-electrode 22 side as the basis of an intervention of water, and  $H^+$  and  $H_2O$ . It reacts to the electron ( $e^-$ ) which has circulated oxygen ( $O_2$ ) and the external circuit 24 in an oxidizer on the negative electrode 22, water ( $H_2O$ ) is generated, and it is discharged out of a fuel cell. At this time, the flow of the electron ( $e^-$ ) which circulated can use the external circuit 24 as electrical energy of a direct current.

#### [0005]

[Problem(s) to be Solved by the Invention]Although water vapor electrolysis and fuel cell operation are performed by the composition mentioned above, the place where an electrode reaction occurs at this time will be limited to the three-phase zone 15 which the solid electrolyte 11, the anode 13, and oxygen gas ( $O_2$ ) touch, as shown in drawing 7, if water vapor electrolysis is taken for an example. As

a result, in order to raise electrode performance, it is necessary to produce an electrode densely. However, when an electrode is produced densely, gas diffusion ability worsens, as a result electrode performance gets worse and it becomes an opposite effect.

[0006]When performing water-vapor-electrolysis operation, it energizes compulsorily, but when a closed space exists in a solid electrolyte / anode interface at this time, the oxygen pressure in that closed space increases unusually, and there is a problem that an electrode exfoliates. For example, when there was a closed space by using  $\text{La}_x\text{Sr}_{1-x}\text{Mn}_3$  as an anode and  $600\text{mAcm}^{-2}$  was energized, there was a problem of separating within 1 hour.

[0007]An object of this invention is to provide the solid electrolyte which increases an effective reaction surface product and can ease the rise of the oxygen pressure in a closed space at the time of electrolysis operation, etc., holding good gas diffusion ability in view of the situation described above.

[0008]

[Means for Solving the Problem]Composition of a solid electrolyte concerning this invention which attains said purpose, An anode and a negative electrode are arranged on both sides, in a solid electrolyte used for high temperature form water vapor electrolysis or a high temperature form fuel cell, a conductive thin film layer is provided in the surface of a main part of a solid electrolyte by the side of the above-mentioned anode, and a porosity anode is provided in the surface of the thin film layer concerned.

[0009]Hereafter, the contents of this invention are explained.

[0010]An outline which used a solid electrolyte concerning this invention for monotonous type elevated-temperature electrolysis is shown in drawing 1. As shown in the figure, the main part 101 of an electrolyte consists of YSZ(s) (Yttria Stabilized Zirconia) as usual, The conductive thin film layer 102 is formed in the surface which becomes that anode side, and the porosity anode ( $\text{LaSrMrO}_3$  system) 103 is formed via this conductive thin film layer 102. The negative electrode ( $\text{NiO/YSZ}$ ) 104 of the same composition as usual is arranged on the other side of the main part 101 of an electrolyte.

[0011]Here, in the above-mentioned conductive thin film layer (henceforth "the thin film layer 102") 102, a thin boundary layer which has hole conductivity and oxygen ion conductivity is said, and what causes an electrode reaction shown below "\*/ 1" according to an interface of this thin film layer 102 and gaseous phase is said. As a material which forms this thin film layer 102, Mn system oxide,  $\text{LaMrO}_3$ ,  $\text{MnO}(\text{La}, \text{Ca})_3$ ,  $\text{MnO}(\text{La}, \text{Sr})_3$ , etc. can be mentioned, and that thickness is 0.1 micrometer - 5 micrometers.

[0012]

[Formula 1] $2\text{O}^{2-} + 4\text{h}^+ \rightarrow \text{O}_2 \text{**} \quad (1)$

[0013]That is, as shown in drawing 2, in the interface of the anode 103 and the thin film layer 102, a hole ( $\text{h}^+$ ) generates to the thin film layer 102 side concerned, and this hole ( $\text{h}^+$ ) diffuses the inside of the thin film layer 102, and is supplied to the reaction of the above-mentioned (1) formula.

[0014]On the other hand, since an electric potential gradient will be formed into the thin film layer 102 of that hole conduction nature if the oxygen pressure in this closed space increases when there is a closed space as shown in drawing 3, in the closed space 104 concerned, the reaction shown in the "\*/ 2" which is a backward reaction of the above-mentioned (1) formula advances, and, as a result, the rise of internal pressure is eased.

[0015]

[Formula 2] $\text{O}_2 \rightarrow 2\text{O}^{2-} + 4\text{h}^+ \quad (2)$

[0016]Therefore, in this invention, form the conductive thin film layer 102 as a boundary layer which has hole conductivity and oxygen ion conductivity in the surface of the main part 101 of a solid electrolyte which touches an anode, and. Since the porous electrode 103 which has electron conductivity and gas permeation nature via this thin film layer 102 was formed, The charge transfer reaction shown above "\*/ 1" can continue and start on all the surfaces of the main part 101 of a solid electrolyte, and the oxygen pressure rise in an anode closed space can be eased at the time of water-vapor-electrolysis operation.

[0017]<Example of an examination> An example of an examination which shows an effect of this

invention below is explained with reference to drawings (graph).

[0018]A "current-potential curve" in an anode at the time of supplying a steam to drawing 4 at temperature of 1000 \*\* at a negative electrode, and performing water vapor electrolysis is shown. As shown in the figure, when current density (horizontal axis) is increased, anode potential shows a tendency for the powerless more conventional cell to just become large. That is, compared with YSZ interface Pt electrode which is not processed [ which was shown by \*\* / conventional ], in an example of an exam shown by -O which provided a thin film layer, change of potential was small and it checked that there was little voltage for obtaining fixed current density, and it ended.

[0019]It examined also about the stability of potential which an anode at the time of carrying out anode energization of  $600\text{mAcm}^{-2}$  to an anode shows. This result is shown in drawing 5. It checked that performance of YSZ interface Pt electrode which is not processed [ which is shown by \*\* as shown in the figure / conventional ] was stabilized, and was operating from for 130 hours or more with low voltage to a gradually worsening tendency being shown in an example of an exam shown by -O which provided a thin film layer.

[0020]

[Example]Hereafter, one suitable example of the solid electrolyte concerning this invention is described.

[0021]It explains taking the case of the solid electrolyte used for a high temperature form water-vapor-electrolysis device in this example. The main part 101 of a solid electrolyte is made into the yttrium-stabilized zirconia (YSZ) stable by 8-mol% of yttria here. Alcohol and a surface-active agent were added and slurried to a 0.5-micrometer particle, and after carrying and carrying out natural seasoning of this slurry on a Teflon sheet, it calcinated in the air at 1400 \*\* for 1 hour. This obtained stabilized zirconia board is a 25 mmphi disk, and thickness is 500 micrometers.  $\text{La}_x\text{Sr}_{1-x}\text{MnO}_3$  (LSM) slurried on the surface of this main part 101 of a solid electrolyte was thinly applied to one field of a disk by 10 mmphi, and it calcinated at 1300 \*\*. After dropping this calcinated LSM on emery paper and washing by ethanol, liquefied Pt paste was thinly applied to that surface, and it calcinated at 1100 \*\* for 1 hour, and was considered as the anode.

[0022]It checked that Mn etc. had diffused this obtained solid electrolyte in the anode / YSZ interface by XPS (X linear-light electronic-spectroscopic-analysis device).

[0023]

[Effect of the Invention]As mentioned above, as stated with the example of an examination, and the example, since the solid electrolyte concerning this invention provided the conductive thin film layer in the surface of the main part of a solid electrolyte, it continues throughout the the reaction of it is attained. Even if the internal pressure in a closed space at the time of water vapor electrolysis rises, an electric potential gradient is formed in a conductive thin film layer, the relaxation effect is revealed, there is no exfoliation of an electrode like before, a long time can be covered, and a stable operation can be carried out with low voltage.

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[Translation done.]

## \* NOTICES \*

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- 1.This document has been translated by computer. So the translation may not reflect the original precisely.
- 2.\*\*\*\* shows the word which can not be translated.
- 3.In the drawings, any words are not translated.

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DESCRIPTION OF DRAWINGS

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## [Brief Description of the Drawings]

[Drawing 1]It is a schematic diagram of the solid oxide type water-vapor-electrolysis device concerning this example.

[Drawing 2]It is an outline figure of a reaction [ / near the anode of drawing 1 ].

[Drawing 3]It is an outline figure of the oxygen rise relaxation reaction in a closed space at the time of water vapor electrolysis.

[Drawing 4]It is a performance comparison figure in the water vapor electrolysis of this invention and a conventional example.

[Drawing 5]It is an operation stability comparison figure in the water vapor electrolysis of this invention and a conventional example.

[Drawing 6]It is a schematic diagram showing the principle of the conventional solid oxide type water-vapor-electrolysis device.

[Drawing 7]It is an outline figure of a reaction [ / near the anode of drawing 6 ].

[Drawing 8]It is a principle figure of water vapor electrolysis.

[Drawing 9]It is a principle figure of a fuel cell.

## [Description of Notations]

101 The main part of a solid electrolyte

102 Conductive thin film layer

103 Porosity anode

104 Negative electrode

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[Translation done.]

## \* NOTICES \*

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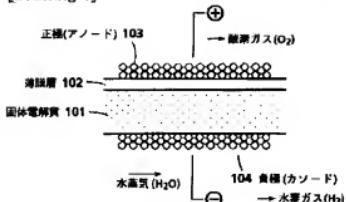
1. This document has been translated by computer. So the translation may not reflect the original precisely.

2.\*\*\*\* shows the word which can not be translated.

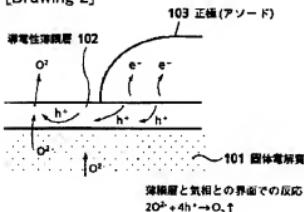
3. In the drawings, any words are not translated.

## DRAWINGS

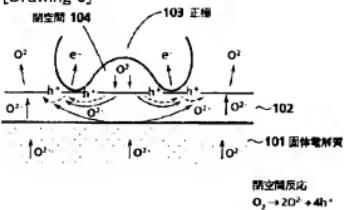
## [Drawing 1]



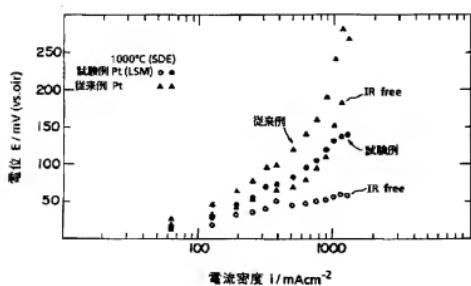
## [Drawing 2]



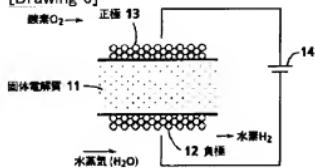
## [Drawing 3]



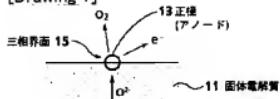
## [Drawing 4]



[Drawing 6]

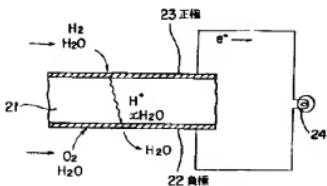


[Drawing 7]

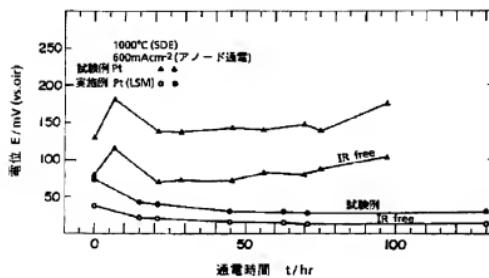


[Drawing 9]

燃料電池の原理図

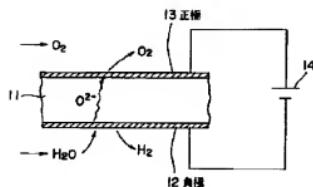


[Drawing 5]



[Drawing 8]

水蒸気電解の原理図



[Translation done.]